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Helmet-Mounted Displays and Facial Injury in U.S. Army AH-64A Apache Accidents (Reprint)

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There is concern that the helmet display unit (HDU) used by AH-64 Apache helicopter pilots might contribute to facial injury in a crash. The U.S. Army accident database was searched for HDU-related injuries in survivable Apache accidents 1985-1995. Four aviators in three crashes sustained HDU-related injury. These involved three periorbital contusions and two minor eye injuries. There were no sequalae. This equates to an incidence of 0.57 injured individuals per 100,000 flying hours or 8.0 injured aviators per 100 survivable Class A-C accidents in which the HDU was worn. Applying these data to the projected UK Army Apache flying hour programme suggests that one HDU-related injury might be encountered approximately every 10.1 years. This estimate should be interpreted with caution. Serious injury remains a possibility due to the proximity of the HDU to the eye and face.

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Helmet-Mounted Displays And Facial Injury In US Army AH-64A Apache Accidents

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SUMMARY: There is concern that the helmet display unit (HDU) used by AH-64 Apache helicopter pilots might contribute to facial injury in a crash. The US Army accident database was searched for HDU-related injuries in survivable Apache accidents 1985-1995. Four aviators in three crashes sustained HDU-related injury. These involved three periorbital contusions and two minor eye injuries. There were no sequelae. This equates to an incidence of 0.57 injured individuals per 100,000 flying hours or 8.0 injured aviators per 100 survivable Class A-C accidents in which the HDU was worn. Applying these data to the projected UK Army Apache flying hour programme suggests that one HDU-related injury might be encountered approximately every 10.1 years. This estimate should be interpreted with caution. Serious injury remains a possibility due to the proximity of the HDU to the eye and face.

Introduction

The procurement of the WAH-64 (Apache) Attack Helicopter by the British Army has generated considerable interest in UK aeromedical circles (1,2). While the Apache has many enhanced safety features (e.g., crashworthy fuel systems, energy-attenuating seats), there are potential safety hazards inherent in its design. Of particular concern is the helmet-mounted display.

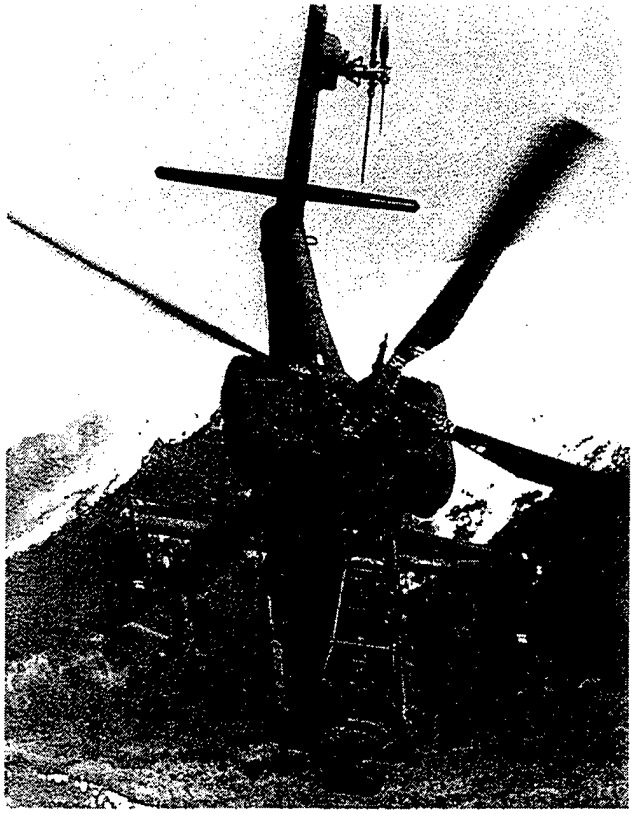

Fig 1. The US Army AH-64A helicopter (US Army photograph).

The AH-64A Apache is a tandem seat, dual engine attack helicopter (Fig 1) that is equipped with an integrated helmet and display sighting system (IHADSS) (Figs 2, 3, 4). This

Fig 2. The AH-64 integrated helmet and display sighting system (IHADSS) helmet. Note the proximity of the HDU to the right side of the aviator's face.

system provides sensor video and/or symbology to each crewmember via a HDU (Fig 3). The HDU contains a 1-inch cathode ray tube (CRT) and attaches to the right side of the helmet, positioning a polycarbonate combiner lens directly in front of the pilot's eye. When in use, the HDU usually rests on the pilot's right cheek; when not needed, it can be rotated away from the face.

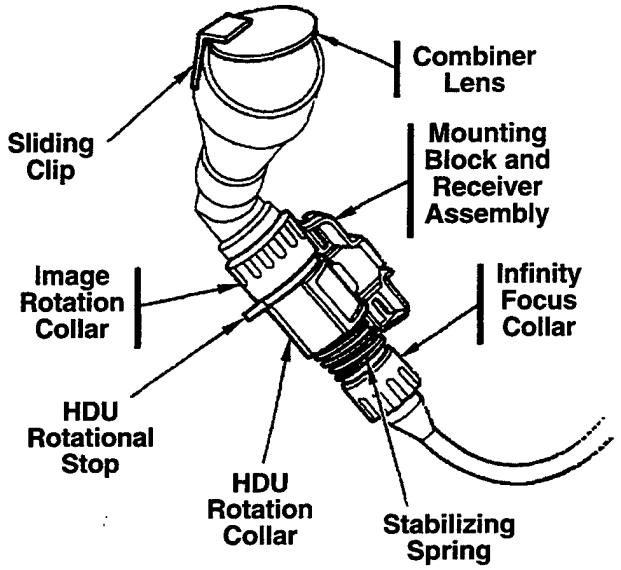

Fig. 3. The AH-64 helmet display unit (HDU) (5).

During a crash sequence, the helicopter pilot is exposed to a variety of potentially lethal forces. Although many injuries are due purely to internal decelerative forces, the most common injury mechanism in US Army helicopter crashes is contact with objects within the cockpit (6). These objects can be divided into two groups: those that are mounted on the aviator's head and those that are attached to the cockpit structure. Examples of the former include the Apache HDU and night vision goggles (NVGs) (7).

These visual aids must be worn extremely close to the aviator's eye(s) and face, constituting a potential injury hazard. The rationale for concern is not that the HDU or NVG will independently cause injury, but rather that in a crash an otherwise blunt impact from a cockpit surface could be focused on critical structures such as the eye or orbit. The HDU combiner lens is made of polycarbonate, so fragmentation is unlikely, but it is positioned at such an angle that orbital injury remains a hazard (Fig. 2). To date no HDU injury analysis has been published.

Since the cockpit environment and HDU design for the WAH-64 helicopter are essentially unchanged from the AH-64A HDU that has been in use for over ten years, a retrospective injury analysis would be relevant to current UK Army concerns. The purpose of this paper is to review the US Army accident experience to determine the incidence of facial injury due to the AH-64A HDU. This information will then be used to predict rates of HDU-related injury in the UK Attack Helicopter program.

Methods

The US Army Safety Management Information System (ASMIS) computerised database was searched for AH-64 accidents involving injuries related to helmet-mounted displays. The ASMIS database, maintained at the US Army Safety Center, Fort Rucker, Alabama, is a valuable safety resource, containing 25 years of detailed accident information. US Army accidents are graded according to cost and injury severity. Current accident classification criteria are summarised in Table 1 (8).

Table 1. Current US Army aircraft accident and incident classifications (8).

Accident Class	Property Cost	Injury severity
Class A accident	>$1,000,000	Fatality or permanent total disability
Class B accident	>$200,000	Permanent partial disability or >4 days hospitalised.
Class C accident	>$10,000	Lost-worktime case.
Class D accident	>$2,000	Any other injury requiring treatment.
Class E incident	<$2,000	None.

Meeting either the criterion cost or the injury severity qualifies an accident for a given class. An accident is also considered Class A if there is total loss of an aircraft, regardless of cost. During the study period (1988), property cost criteria were adjusted for inflation. These changes did not affect the outcome of this study.

The database was searched for relevant survivable or partially survivable (hereafter referred to as 'survivable') Class A-C accidents from 1985 to 1995, inclusive, using several retrieval strategies. First, accidents were sought in which an injury had been formally attributed to the HDU. The second search included any accident in which right-sided (i.e., the side on which the HDU is worn) facial injury occurred to a victim of an AH-64 accident in which an HDU was used. Finally, narrative searches were conducted for the following key words: "helmet display unit," and "HDU." All accidents meeting search criteria were reviewed on-line via ASMIS and irrelevant accidents were discarded. The hard-copy accident reports for the remaining cases were then studied, and a determination made regarding possible HDU injury. Separately, several searches were performed to provide denominator data (e.g., number of AH-64 accidents, flight hours, etc.)

Results

HDU Injuries

Only four cases of unambiguous HDU-related injury were found (Table 2), occurring in three accident aircraft. These involved three periorbital contusions and two ocular injuries. None of the victims wore spectacles at the time of the accident, although one was wearing contact lenses. There were no long-term sequelae from any of these injuries, and all four individuals returned to flying.

Table 2. HDU-related facial injuries.

Accident #	Victim Duty	Body Region	Injury Type	Injury Severity	Comments
1	Rear Seat	R. cornea	Laceration/ abrasion	Minor	Contact lens dislodged
2	Rear Seat	R. superior eyelid	Contusion	Minimal	
2	Front Seat	R. superior and inferior eyelids	Contusion	Minimal	HDU was rotated away at impact
3	Front Seat	R.Sclera R. Orbit	Haemorrhage Contusion	Minimal Minimal	

Given that there were four individuals injured and 703,666 AH-64A hours flown during the study period, the incidence of an individual suffering an HDU-related facial injury was 0.57 per 100,000 AH-64A flying hours. (While it would be more useful to state the injury rate in terms of hours flown with the HDU in use, these data are not available.)

However, it is possible to state the proportion of accidents occurring while the HDU was in use that involved HDU-related injury. Considering survivable AH-64 accidents in which the HDU was used, there were 8 injured aircrew per 100 Class A-C accidents (4/50), and 26.7 per 100 Class A accidents (4/15).

In terms of individual risk of injury, an AH-64 crewmember wearing an HDU had a 4.0% chance of HDU-related injury if he or she is involved in a survivable Class A-C accident (4/99) and a 13.8% chance in a survivable Class A accident (4/29). (It was assumed that both crew were wearing the HDU if the accident was coded as involving HDU use, excepting one accident in which the report stated that the co-pilot/gunner was using NVGs.)

Discussion

HDU Injuries

Given the conspicuous proximity of the HDU to the Apache pilot's face, it is surprising that so few attributable injuries were discovered. The reason for this is unknown, but one contributing factor may be the various crashworthy design features incorporated into the Apache that reduce the forces transmitted to the pilot. Another factor might be the "quick release" attachment of the HDU to the flight helmet. That is, the HDU may have already separated by the time the head contacted cockpit structures during the impact sequence. Shannon and Mason recently showed that a similar break-away feature in NVG's is associated with a lower incidence of head and neck injury (9). Additionally, it is possible that some aviators avoided injury by rotating the HDU away from the face to the "stowed" position (note that this does not preclude injury Table 2. It is also probable that some number of minor facial injuries were unreported, but it is unlikely that any major HDU-related injury in a survivable accident went undiscovered.

Predicting AH injury rates.

The prediction of future accident rates is risky and dependent on many factors. The low number of observed HDU-related injuries makes these estimates particularly unstable. Nonetheless, applying these US Army HDU-related injury rates to the forecast UK Attack Helicopter programme reveals the following:

Based on a fleet of 58 aircraft, each flying 300 hours/year (personal communication, SJ Durnford, 1997), the annual flying hour programme will be 17,400 hours. Applying the US injury rate yields an HDU-related injury rate for the UK of 0.099 injuries per year, or one injured individual every 10.1 years. This makes the generous assumption that the UK programme will be similar to past US Army Apache flying, especially in terms of accident risk exposure, crash profiles, and the proportion of flying that involves the HDU.

Study Limitations

This retrospective accident database review may have underestimated injury rates for several reasons. First, there may have been simple errors by investigators, flight surgeons, data transcribers or computer data entry personnel. For example, two certain HDU-related injuries were coded in the ASMIS computer as being helmet-related. Second, there was a tendency for minor injuries to go unrecorded in victims suffering multiple severe injuries. This can be a major problem for nonsurvivable accidents, and may have occurred in severe but survivable accidents as well. For example, a victim with severe thoraco-abdominal trauma and extremity amputations is unlikely to have every minor facial laceration recorded in the ASMIS computer. Third, inadequate analysis of injury mechanism by the board flight surgeon frustrated the analysis in at least one survivable AH-64 accident involving a suspicious head injury. Finally, the assumption that both crewmembers were always wearing their HDUs at impact almost certainly exaggerated the number of uninjured HDU-users. This would have underestimated individual injury risk by artificially enlarging the denominators.

It is important to note that despite the apparently reassuring results of this study, serious injury could no doubt be suffered if the HDU was struck at an unfavourable angle. Every accident is different, and the lack of any serious HDU-related injury to date does not eliminate the hazard or the need for further risk reduction.

Conclusions

Between 1985 and 1995, inclusive, there were four US Army aviators in three AH-64 Apache helicopter crashes who suffered facial injuries that were definitely ascribed to the HDU. None of these injuries was severe or had any lasting sequelae.

Based on the US Army accident experience and the projected UK Apache flying hour programme, it is estimated that one HDU-related facial injury could be expected to occur approximately every 10.1 years. This

estimate depends on a number of assumptions and should be interpreted with caution.

Serious injury remains a possibility due to the proximity of the HDU to the eye and orbit.

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